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199942515

(71) Applicant(s)
Malcolm Leonard Stephen Dean

(72) Inventor(s)
Malcolm Leonard Stephen Dean

(74) Agent/Attorney
INTELLPRO,Patent and Trade Mark Attorneys,GPO Box 1339,BRISBANE QLD 4001

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ABSTRACT

A module comprising the groupings 11 and 12 remains the same for all embodiments. Assemblies 11 and 12 are effectively side-by-side unequal co-axial assemblies. Assembly 11 is the first unequal coaxial assembly and comprises of a cam {sun-element} (17), bearing (18) and rollers {planet-element} (20).

Assembly 12 is the second unequal coaxial assembly and comprises of a rotor (15), cam (16), and rollers (19). The planet elements of the assemblies are constrained in the one body, the ring elements also share the one body so they are likewise constrained.

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COMPLETE SPECIFICATION FOR A PETTY PATENT

Name of Applicant:	MALCOLM LEONARD STEPHEN DEAN
Actual Inventor(s):	MALCOLM LEONARD STEPHEN DEAN
Address for Service:	INTELLPRO Patent & Trade Mark Attorneys Level 7, Reserve Bank Building 102 Adelaide Street BRISBANE, QLD, 4000 (GPO Box 1339, BRISBANE, 4001)
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The following statement is a full description of this invention, including the best method of performing it known to me:

A CONVERTOR

TECHNICAL FIELD OF THE INVENTION

THIS invention relates to a convertor of the epicyclic type. The present application is a divisional of parent application No. 42515/99.

BACKGROUND TO THE INVENTION

Epicyclic gear trains are common. Polder describes variable epicyclic gear trains in his publication "A Network Theory for Variable Epicyclic Gear Trains" published in 1969 by Greve Offset N.V. Eindhoven, Netherlands, an epicyclic gear being characterised as a black box unit with three rotating elements which are effectively able to be considered as shafts since any one may comprise an input or output, represented in a mathematical mode as a "three pole" device with one linear equation for angular velocities and two linear equations for torques.

The equation for angular velocities is written in the general form:

$$a\omega_A + b\omega_B + c\omega_C = d$$

where a, b, c and d are co-efficients;

A, B and C specify the respective shafts; and

and ω_A, ω_B and ω_C are the angular velocities of the shafts.

The equations for torque are derived from the equilibrium:

$$\alpha T_A + \beta T_\beta + \gamma T_C = 0$$

where α , β and γ are generally different, the two equations being derived as follows:

eliminating T_C yields the first equation:

$$\left(\frac{\alpha - \gamma}{\beta - \gamma}\right) T_A + T_B = 0$$

$\left(\frac{\alpha-\gamma}{\beta-\gamma}\right)$ is a constant which Polder replaces with $\bar{\imath}_{A/B}\,\bar{\eta}_{B/A}$ giving

$$\bar{\imath}_{A/B}\,\bar{\eta}_{B/A}\,T_A + T_B = 0 \qquad \text{The first torque equation}$$

where $\bar{\imath}_{A/B} = \frac{\omega_A}{\omega_B}$ for $\omega_C = 0$ is called the "binary ratio"

$$\text{and } \bar{\eta}_{B/A} = \frac{1}{\bar{\imath}_{A/B}}\,\bar{\imath}_{A/B}\,\eta_{A/B} = \frac{\omega_B}{\omega_A}\left(\frac{-T_B}{T_B}\right) = \frac{-P_B}{P_A} \quad \text{for } \omega_C = 0$$

where P_B and P_A are shaft powers and $\bar{\eta}_{B/A}$ is referred to as the "binary efficiency".

In the case of epicyclic gears there is no distinction between shafts so suffixes can be transposed. Each consistent transposition of suffixes throughout the three formulae is called a "permutation".

Ternary ratios and ternary efficiencies exist for the situation of three rotating shafts these being represented by:

$$\text{ternary ratio } \hat{\imath}_{A/B} = \frac{\omega_A}{\omega_B}$$

$$\text{ternary efficiency } \hat{\eta}_{B/A} = \frac{-P_B}{P_A}$$

The shaft powers satisfy the equilibrium:

$$P_A + P_B + P_C + P_V = 0$$

where P_V is the dissipative power.

Polder's network theory of variable epicyclic gear trains involves simplifying any epicyclic gear train into an equivalent involving three pole branches, usually a combination of simple three pole transmission branches and three pole epicyclic branches.

Clearly by appropriate selection of the ratios the torque and power characterisation of any epicyclic gear train can be determined.

In this sense the relationships involved in an epicyclic gear train are well defined. Polder suggests a number of variable epicyclic gear trains derived using his network theory.

An object of the present invention is to provide a convertor of the epicyclic type as a useful alternative to the prior art.

OUTLINE OF THE INVENTION

In one aspect the invention provides a convertor having an input and an output and being of the epicyclic type involving interaction of three mechanically distinct rotating elements, namely a sun element, a ring element and a planet carrier element in each of at least first and second unequal co-axial epicyclic assemblies, a first rotating element of the first assembly and a first rotating element of the second assembly being constrained to rotate at a common angular velocity, a second rotating element of the first assembly and a second rotating element of the second assembly being constrained to rotate at a common angular velocity, and control means for progressively changing the gear ratio applied to a load connected to the first rotating elements of the convertor characterised in that the first rotating elements are unequal pairs of the same

mechanical elements of the respective assemblies and in conjunction with respective second rotating elements each represent different respective fixed gear ratios relative to the input and the output of the convertor, the second rotating elements are unequal pairs of the same mechanical elements of the respective assemblies and in conjunction with respective said first rotating elements each represent fixed gear ratios between the input and the output of the convertor, a third element of the second assembly rotating in response to demand for an output low gear stage of operation of the convertor and the control means being operative to progressively increase the output gear ratio and at the same time slow the rotation of the third element in accordance with demand for an output higher gear stage of operation, the control means being operative to increase or decrease the output gear ratio automatically in accordance with the said demand.

In the description "output higher gear stage of operation" means "higher" in the sense of a gear ratio approaching 1:1 ratio as input to output, while "output low gear stage of operation" means an output gearing in the opposite sense generally corresponding to a lower output angular velocity.

The first rotating elements are typically the ring elements of the respective assemblies. The ring elements are preferably outer bodies having spaced endless scollop guides, each scollop guide having unequal relative numbers of scollops to rollers in either side depending on the required gear ratios for a particular application and the guides being adapted to receive sets of planet rollers of the planet carrier elements.

The second rotating elements are typically the planet carrier elements of the respective assemblies. The planet carrier elements are typically formed as an integral unit housing spaced sets of rollers of unequal numbers relative to the number of scallops, with the rollers corresponding to the planets of each assembly, the rollers bridging between the scollop guides of the outer bodies and the third elements of the assemblies. The planet carrier is preferably constrained by a rotation blocking means

to travel in one direction only. The rotation blocking means is preferably a selective rotation blocking means enabling selection of rotation of the second rotating elements in forward or reverse direction.

The third elements of the assemblies are preferably sun elements in the form of respective cams, each cam typically having a roller bearing assembly separating the cam into an inner cam and a cam ring able to travel opposite the direction of the inner cam.

The control means is typically a centrifugal clutch operable to slip to partially engage the third element of the second assembly across a continuous range of output gear ratios between fully disengaged and fully engaged positions of the centrifugal clutch at respective predetermined low and high output angular velocities.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a section corresponding to Fig 4A of the parent application 42515/99;and

Figure 2 a section corresponding to Figure 6 of parent application 42515/99

METHOD OF PERFORMANCE

Referring to the drawings there are illustrated in Figure 1 and Figure 2 two convertors employing the same general configuration in that both have an epicyclic unit or module shown collectively in relation to the components concerning numerals 10 in Figure 2 and the numerals 11 and 12 in Figure 1 and shown here in preferred form and the inclusion of this module to all embodiments being the central concept of the present invention. In the example illustrated in Figure 1, the module employs first and second unequal co-axial epicyclic assemblies 11 and 12, these are both of the cycloidal type, that is, employing scollops and rollers.

While each module is shown generally with the numerals 10,11 and 12 in Figures 1 and 2 the particular module used in each case differs in terms of specific arrangement due to the different applications.

Modules employed will vary in specific arrangement for other applications as well. What is common is that each of the assemblies 10, 11, 12 share a common planet element and a common ring element. The sun elements are separate cams, rollers bridge between the cams and the scallops. The planet element comprises a planet carrier bridging axially between the assemblies having opposite sides which are unequal in terms of the number of rollers relative to the number of scallops carried by the planet carrier, while the ring element comprises an outer body having scallops arranged so the assemblies each represent different fixed ratios relative to an input and an output.

This means the planet carriers of the two assemblies are constrained to rotate at the same angular velocity. It also means that the outer bodies of the two assemblies are constrained to rotate at the same angular velocity. In the illustrated embodiments the angular velocity of the outer body could be zero.

In each assembly the cams are eccentric cams which rotate in co-operation with the scallops and roller configuration of the respective assemblies. One of the cams is driven by an input shaft, this will cause the output, that is the outer body, to rotate while the other cam rotates in the opposite direction. The output gear ratio is influenced by the angular velocity of the second cam, thus various braking arrangements applied to the second cam will influence the output in a controllable fashion according to demand.

While the above description deals with the general features involved the following description will enable understanding of the application of the invention to the two specific applications of Figure 1 and Figure 2.

Figure 1 shows a convertor according to the invention an input, which is a rotor (14) an output (21) and electrical coil and permanent magnet arrangements (23 – 25)

that apply torques respectively to rotors (14, 15) and a planet element in the form of a cage (22).

Items 23, 24 and 25 are arrangements of permanent magnets and electrical coils so that with electricity flowing through the coils, interacting magnetic fields are produced which cause a torque on the rotors (14, 15) and cage (22) respectively. The electricity supply can be adjusted individually for each of items 23 to 25.

The rotor (14) and input shaft (13) are combined as an integrated part in this module. As an alternative, the rotor (14) could be removed and the input could be solely from an external motive source driving the input shaft (13). The point is the module comprising the groupings 11 and 12 remains the same.

Assembly 11 is the first unequal coaxial assembly and comprises of a cam {sun-element} (17), bearing (18) and rollers {planet-element} (20). The cam (17) is fixed to the input shaft (13), which is therefore fixed to the input. The bearing (18) has an inner sleeve fitted to the outer diameter of the cam (17). The bearing has an outer sleeve, the outer sleeve of the bearing (18) makes contact with the rollers (20). As the input rotates, the cam (17) causes the bearing (18) to move in an eccentric fashion. This causes the rollers (20) to be cyclically displaced away and towards the central axis of the convertor, the total displacement relative to this central axis, being twice the cam axis offset from this axis. The rollers (20) are located in equally spaced guides in the cage {planet element} (22). The rollers (20) make contact with scallops in the output {ring element}(21). For both assemblies (11 & 12), the number of scallops relative to the number rollers in contact with the scallops, determines the direction of rotation it would rotate the output (21) if the cage (22) was held still. One more scallop than the number of rollers gives an output rotation direction the same as the cam rotation. One less scallop than the number of rollers would give an output rotation the opposite to the cam rotation. The scallops are so shaped that as the rollers are acted on by the cam, the

scallops rotate relative to the cage at a constant angular velocity ratio to that of the cam. The action between the cam (17), bearing (18) and rollers (20) against the output (21), causes an equal and opposite reaction on the cage (22), tending to rotate it in the opposite direction to the rotation of the output (21). The cage (22) is constrained by a rotation blocking means in such a way as to allow the cage (22) to only rotate in a direction the same as the output (21). Therefore because of the reactive forces, the cage (22) will be held against the rotation blocking means and will therefore be stationary relative to the frame (26) with just the actions of assembly 11 alone. The magnetic effects caused by items 25 can drive the cage (22) (with the same action as 23 does on item 14). This torque caused by items 25 is an ancillary action and not necessary for the central concept of the present invention. The rollers will rotate about there own axis as they move in relation to the scallops. The bearing (18), is added to eliminate the sliding action of roller (20) against cam (17), which would occur (if they were in direct contact) because of the difference in their circumferential speeds. The output (21) is constrained to rotate about the central axis of the input shaft (13). The cyclical movement of the rollers (20) acting on the scallops alone, causes the output (21) to rotate at a reduced rotational speed depending on the number of rollers and scallops.

For example, if the cage (22) is constrained from being able to rotate, and if assembly 11 has four rollers (20), and there are five scallops in the output (21), the ratio would be one output (21) revolution for every five revolutions of the cam (17) with the output (21) rotating in the same direction as the cam (17).

Assembly 12 is the second unequal coaxial assembly and comprises of a rotor (15), cam (16), and rollers (19). The scallops in the output (21) make contact with the rollers (19) which make contact with the cam (16). The cam (16) is fixed to the rotor (15). To reduce frictional losses, a bearing would be fitted to the outside diameter of the

cam (16). The number of scallops and rollers for assembly 12 are different to the numbers for assembly 11. The rollers are located in equally spaced guides in the cage (22). The cage therefore bridges axially between assemblies 11 and 12 and the rollers (19) are constrained to rotate at the same angular velocity about the central axis of the input shaft (13) as the rollers (20) of assembly 11. The numbers of scallops and rollers are such that if the cage (22) is held relative to the frame (26), the output (21) tends to cause the cam (16) to rotate with an angular velocity in the opposite direction to cam (17).

For example, if the cage (22) is constrained from being able to rotate, and if assembly 12 has four rollers (20), and there are three scallops in the output (21), the ratio would be one output (21) revolution for every three revolutions of the cam (16), with the output (21) rotating in the opposite direction to the cam (16).

If the assembly 11 cam (17) is caused to rotate, the output (21) will rotate at another angular velocity, being a fixed ratio to the input angular velocity. The assembly 12 cam (16) will rotate at an angular velocity dependent on the fixed ratio of assembly 12, and for the central concept of the present invention, in the opposite direction to cam (17). If assembly 12 was arranged so that cam (16) rotated in the same direction as cam (17), the output would be reversed if cam (16) was braked. The cam (16) will have no effect on the output angular velocity until the electrical coils of items 24 are activated. With the electrical coils activated, a torque is transmitted through the rotor (15) to the cam (16). The electrical coils could be activated so that the torque acts in the same or opposite direction as the rotation of the cam (16). If the torque acts in the same direction as the rotation of the cam (16), the output would rotate at the angular velocity determined by the fixed ratio but with an increased torque dependant on the amount of torque contributed by items 24. The torque from items 24 act in the opposite direction of rotation of the cam (16) (ie. the same direction as the input shaft (13)). In this case,

assembly 12 will act so as to try and cause the output (21), to rotate in the opposite direction and the cage (22) in the same direction as the input. In simplistic terms, the opposite actions on the output and cage caused by cam (16) tend to 'lock' the cage (22) to the input rotation. The cage (22) is free to rotate in the direction of the input (cam (17)). The cage (22) therefore tends to cause the output (21) to rotate as one with the input. The rollers (20) rotation about the central axis of the input shaft (13) due to the action of the cam (17), has superimposed on it a rotation about this central axis due to the rotation of the cage (22) in the direction of the input. It is this superimposed rotation that causes the output to increase its angular velocity relative to the input angular velocity. The amount of rotation of the cage (22) and therefore the amount of superimposed rotation, is determined by the relative differences in the output resistive torque (hereafter called the 'load') and the input torque from cam (17) and items 24. When the 'load' lowers relatively and the torque from items 24 is increased, the less the torque required from cam (17). As the proportion of torque from cam (16) relative to cam (17) increases, the more the output (21) tends to be 'locked' to the input and the more the ratio of input to output angular velocity tends to approach 1:1. The output gear ratio therefore can be progressively decreased from the fixed ratio of the first assembly to a 1:1 ratio by progressively increasing the torque acting on the cam (16) from zero to a value that causes the cage (22) to be 'locked' fully to the input. The output torque is inversely proportional to the output angular velocity..

Figure 2 shows another embodiment of a convertor, in this case there is a combination of a module 10 with extensions (on the right-hand half) that enable further multiple fixed ratios to be obtained from the one convertor. The module 10 shows the central concept of the present invention. The input is via a separate motive source (not shown) acting through the input shaft (13). The output is the ring element or body (21).

The first unequal coaxial assembly comprises of a cam {sun-gear} (17), and rollers {planet-gears} (20) and the ring element or body (21). The cam (17) is fixed to the input shaft (13).The outer diameter of the cam (17) makes contact with the rollers (20). As the input rotates, the cam (17) outer diameter moves in an eccentric fashion. This causes the rollers (20) to be cyclically displaced away and towards the central axis of the convertor, the total displacement relative to this central axis, being twice the cam axis offset from this axis. The rollers (20) are located in equally spaced guides in the cage {planet carrier} (22). The rollers (20) make contact with scallops in the output (21). For both assemblies (11 & 12), the number of scallops relative to the number rollers in contact with the scallops, determines the direction of rotation it would rotate the output (21) if the cage (22) was held still. One more scallop than the number of rollers gives an output rotation direction the same as the cam rotation. One less scallop than the number of rollers would give an output rotation the opposite to the cam rotation. The scallops are so shaped that as the rollers are acted on by the cam, the scallops rotate relative to the cage at a constant angular velocity ratio to that of the cam. The action between the cam (17), bearing (18) and rollers (20) against the output (21), causes an equal and opposite reaction on the cage (22), tending to rotate it in the opposite direction to the rotation of the output (21). The cage (22) is constrained by a rotation blocking means in such a way as to allow the cage (22) to only rotate in a direction the same as the output (21). Therefore because of the reactive forces, the cage (22) will be held against the rotation blocking means and will therefore be stationary relative to the frame (the structure holding mounting the motor etc.) with just the actions of assembly 11 alone. The rollers will rotate about there own axis as they move in relation to the scallops. A bearing could be fitted to the outside diameter of the cams (16 & 17) to eliminate the sliding action of roller (19 & 20) against cam (16 & 17), which would occur (if they were in direct contact) because of the difference in their circumferential speeds.

The output (21) is constrained to rotate about the central axis of the input shaft (13). The cyclical movement of the rollers (20) acting on the scallops alone, causes the output (21) to rotate at a reduced rotational speed depending on the number of rollers and scallops.

For example, if the cage (22) is constrained from being able to rotate, and if assembly 11 has four rollers (20), and there are five scallops in the output (21), the ratio would be one output (21) revolution for every five revolutions of the cam (17) with the output (21) rotating in the same direction as the cam (17).

The second unequal coaxial assembly comprises of a cam (16), and rollers (19) and the output (21). The scallops in the output (21) make contact with the rollers (19) which make contact with the cam (16). The number of scallops and rollers for the assembly are different to the first assembly 11. The rollers are located in equally spaced guides in the cage (22). The cage therefore bridges axially between assemblies 11 and 12 and the rollers (19) are constrained to rotate at the same angular velocity about the central axis of the input shaft (13) as the rollers (20) of assembly 11. The numbers of scallops and rollers are such that if the cage (22) is held relative to the frame, the output (21) tends to cause the cam (16) to rotate with an angular velocity in the opposite direction to cam (17).

For example, if the cage (22) is constrained from being able to rotate, and if assembly 12 has four rollers (20), and there are three scallops in the output (21), the ratio would be one output (21) revolution for every three revolutions of the cam (16), with the output (21) rotating in the opposite direction to the cam (16).

If the assembly 11 cam (17) is caused to rotate, the output (21) will rotate at another angular velocity, being a fixed ratio to the input angular velocity. The assembly 12 cam (16) will rotate at an angular velocity dependent on the fixed ratio of assembly 12, and for the central concept of the present invention, in the opposite direction to cam

(17). If assembly 12 was arranged so that cam (16) rotated in the same direction as cam (17), the output would be reversed if cam (16) was braked. The cam (16) will have no effect on the output angular velocity until a torque is made to act on it. Any torque acting on cam (16) could act in the same or opposite direction as the rotation of the cam (16). If the torque acts in the same direction, the output would rotate at the angular velocity determined by the fixed ratio but with an increased torque. As in the previous embodiment the torque acting on cam (16) is in a direction opposite to that of the rotation of the cam (16) (ie. the same direction as the input shaft (13)). In this case, assembly 12 will act so as to try and cause the output (21), to rotate in the opposite direction and the cage (22) in the same direction as the input. In simplistic terms, the opposite actions on the output and cage caused by cam (16) tend to 'lock' the cage (22) to the input rotation. The cage (22) is free to rotate in the direction of the input (cam (17)). The cage (22) therefore tends to cause the output (21) to rotate as one with the input. The rollers (20) rotation about the central axis of the input shaft (13) due to the action of the cam (17), has superimposed on it a rotation about this central axis due to the rotation of the cage (22) in the direction of the input. It is this superimposed rotation that causes the output to increase its angular velocity relative to the input angular velocity. The amount of rotation of the cage (22) and therefore the amount of superimposed rotation, is determined by the relative differences in the output resistive torque (hereafter called the 'load') and the input torque from the cams (17 & 16). When the 'load' lowers relatively and the torque acting on cam (16) is increased, the less is the torque required from cam (17). As the proportion of torque from cam (16) relative to cam (17) increases, the more the output (21) tends to be 'locked' to the input and the more the ratio of input to output angular velocity tends to approach 1:1. The output gear ratio therefore can be progressively decreased from the fixed ratio of the first assembly to a 1:1 ratio by progressively increasing the torque acting on the cam (16) from zero

to a value that causes the cage (22) to be 'locked' fully to the input. The output torque is inversely proportional to the output angular velocity.

The input torque to cam (16) can be through another motive source or a clutch mechanism connecting the input shaft (13) to the extension of cam (16). If a clutch mechanism was used, the control mechanism could be automatic and linked to the output speed through the use of a centrifugal clutch. With a centrifugal clutch arrangement, as the speed of the output increases the clutch engages and tends to turn cam (16) in the same direction as the input, cam (17). So as the output is accelerated at the lower fixed ratio, there will come a stage when the input shaft is spinning at such a speed that the centrifugal clutch starts to engage. As the centrifugal clutch engages, the output gear ratio would progressively decrease to 1:1.

With the addition of other rotation blocking means to this arrangement to constrain other parts to rotate in one direction only, there is the possibility of having sequentially selected multiple ratios with other outputs. For example if the rotation blocking means is connected to cam (16), the body (21) or cages (28), the output will be the body (21), cage (28), and cage (29) respectively. There is also the possibility of arranging the cage (22) so that it protrudes from the right-hand side of figure 2. The cam (16) extension can be also shortened so that it lies totally within the body (21) and its rotation could be controlled by various external or internal means.

Whilst the above has been given by way of illustrative example of the present invention many variations and modifications thereto will be apparent to those skilled in the art without departing from the broad ambit and scope of the invention as herein set out in the appended claims.

CLAIMS:

1. A convertor having an input and an output and being of the epicyclic type involving interaction of three mechanically distinct rotating elements, namely a sun element, a ring element and a planet carrier element in each of at least first and second unequal co-axial epicyclic assemblies, a first rotating element of the first assembly and a first rotating element of the second assembly being constrained to rotate at a common angular velocity, a second rotating element of the first assembly and a second rotating element of the second assembly being constrained to rotate at a common angular velocity, and control means for progressively changing the gear ratio applied to a load connected to the first rotating elements of the convertor characterised in that the first rotating elements are unequal pairs of the same mechanical elements of the respective assemblies and in conjunction with respective second rotating elements each represent different respective fixed gear ratios relative to the input and the output of the convertor, the second rotating elements are unequal pairs of the same mechanical elements of the respective assemblies and in conjunction with respective said first rotating elements each represent fixed gear ratios between the input and the output of the convertor, a third element of the second assembly rotating in response to demand for an output low gear stage of operation of the convertor and the control means being operative to progressively increase or decrease the output gear ratio by controlling rotation of the third element in accordance with demand for an output lower or higher gear stage of operation, the control means thereby being operative to increase or decrease the output gear ratio automatically and progressively in accordance with the said demand.

2. The convertor according to claim 1 wherein the first rotating elements are the ring elements of the respective assemblies, the ring elements being outer bodies having spaced endless scallop guides, each scallop guide having unequal numbers of scallops and the guides being adapted to receive sets of planet rollers of the planet carrier

elements, the second rotating elements being planet carrier elements of the respective assemblies, the planet carrier elements housing spaced sets of rollers of unequal numbers of rollers corresponding to the planets of each assembly, the rollers bridging between the scallop guides of the outer bodies and the third elements of the assemblies, the planet carrier elements being constrained by a rotation blocking means to travel in one direction only, the third elements of the assemblies being sun elements in the form of respective cams.

3. The convertor according to claim 1 wherein the first rotating elements are the ring elements of the respective assemblies, the ring elements being outer bodies having spaced endless scallop guides, each scallop guide having unequal numbers of scallops and the guides being adapted to receive sets of planet rollers of the planet carrier elements, the second rotating elements being planet carrier elements of the respective assemblies, the planet carrier elements housing spaced sets of rollers of unequal numbers of rollers corresponding to the planets of each assembly, the rollers bridging between the scallop guides of the outer bodies and the third elements of the assemblies, the planet carrier elements being constrained by a rotation blocking means to travel in one direction only, the third elements of the assemblies being sun elements in the form of respective cams, the control means being operable to slip to partially engage the third element of the second assembly across a continuous range of output gear ratios between fully disengaged and fully engaged positions at respective predetermined low and high output angular velocities.

DATED this 12th day of JULY, 2001

MALCOLM LEONARD STEPHEN DEAN
By his Patent Attorneys
INTELLPRO

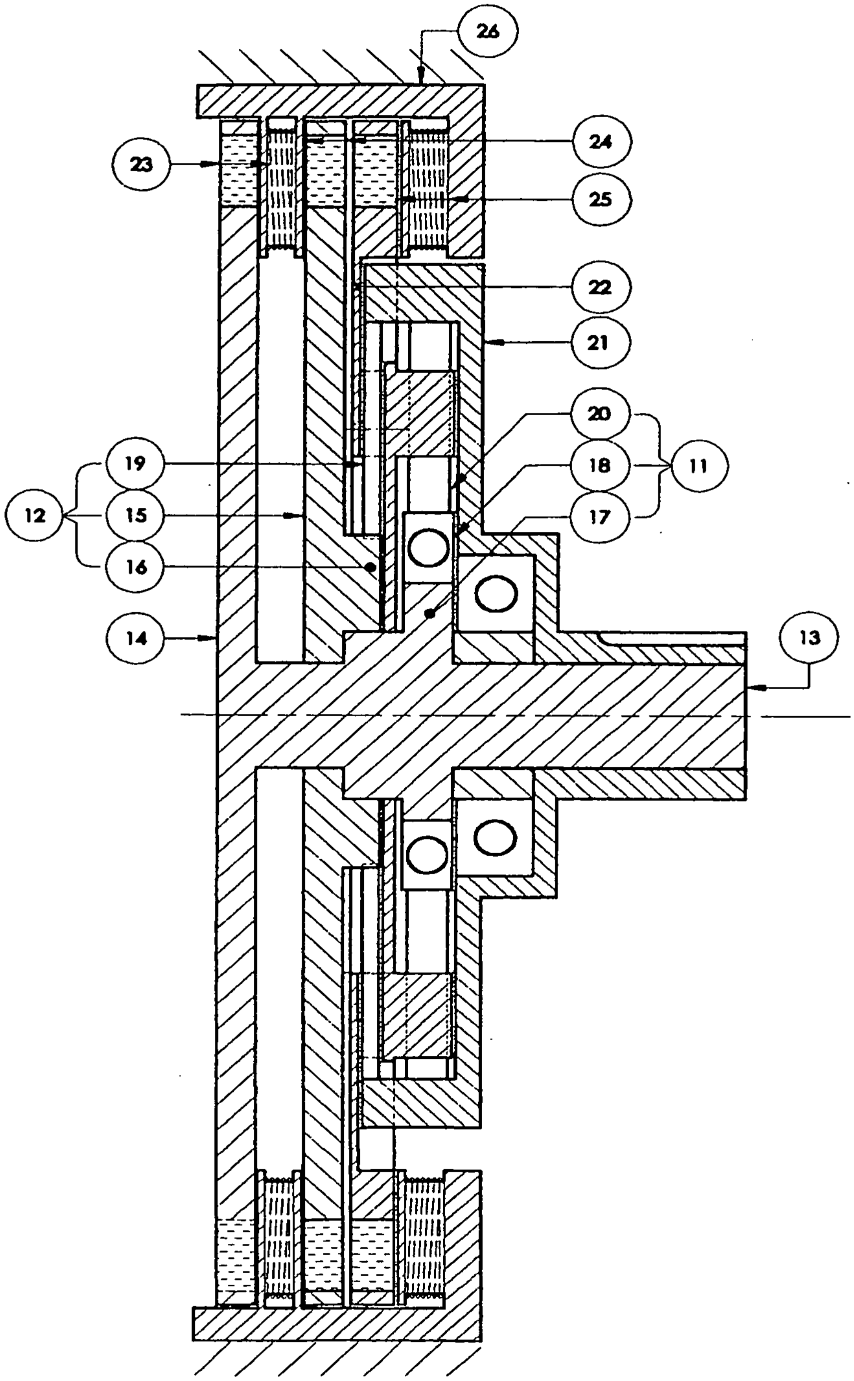

Fig. 1

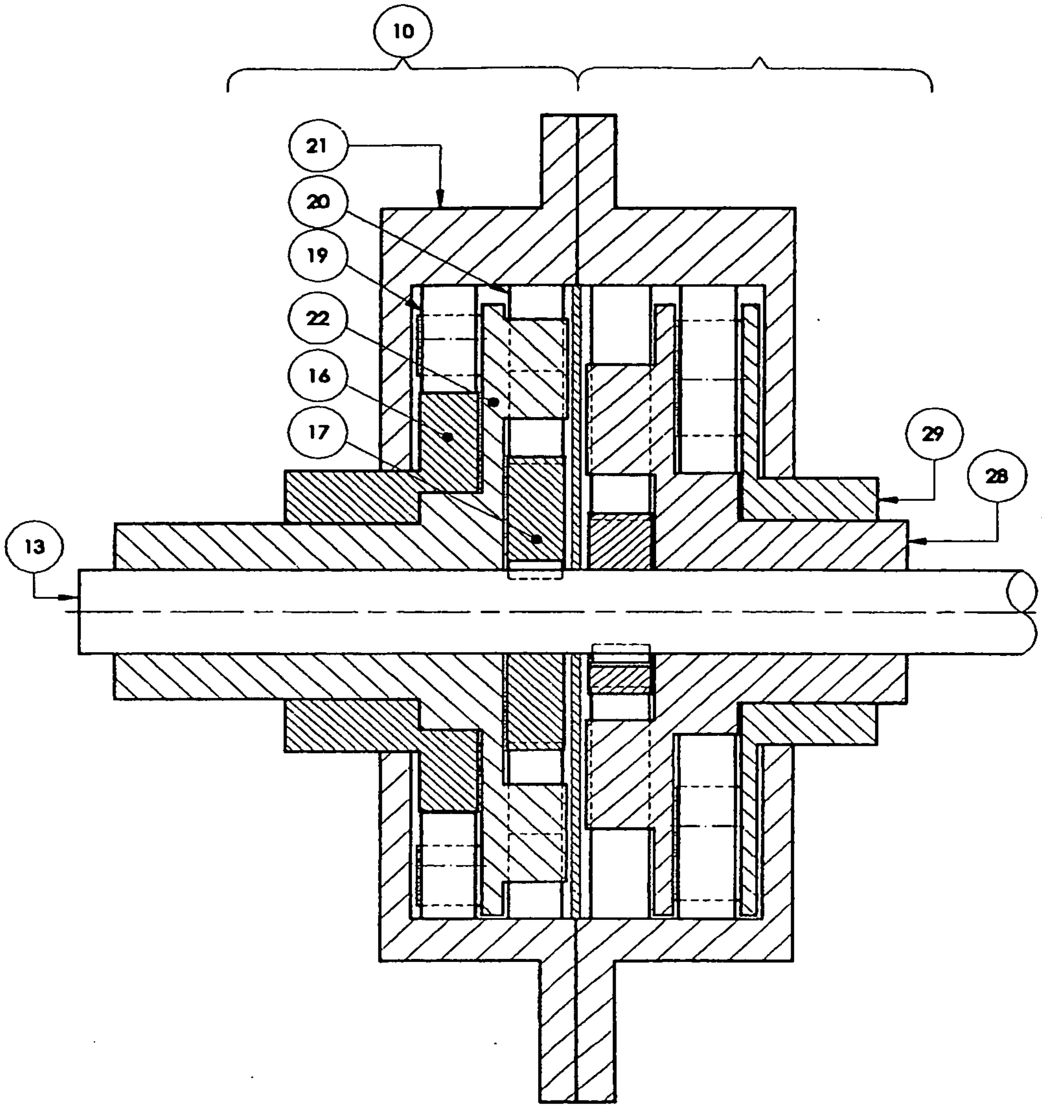

Fig 2